

# Development and Validation of Biota-Sediment Accumulation Factors for the Lower 8.3 Miles of the Lower Passaic River Using Log-linear Regression

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## Abstract

The Lower Passaic River, part of the Diamond Alkali Superfund Site, is a highly impacted tidal urban estuary located in northern New Jersey that has been the focus of intense study, leading to the recent Record of Decision (Mar-2016) by the US EPA for the lower 8.3 miles. An important component of this investigation was the development of quantifiable site-specific relationships between sediment and fish tissue concentrations for the major contaminants, including 2,3,7,8-TCDD, PCBs, DDT, dieldrin, PAHs, copper, lead and mercury. The data for the analyses came from the Superfund investigation as well as NYC harbor studies including CARP and NOAA RE-MAP programs. These relationships were developed for 3 fish and one invertebrate species, representing a range of trophic levels. For organic compounds, the BSAFs were developed based on lipid-normalized and organic carbon-normalized concentrations in fish and sediment, consistent with EPA guidance. For metals, only sediment concentrations were normalized to iron content. Concentrations in both media often spanned orders of magnitude, with sample-specific BSAF and BAF estimates apparently varying with sediment concentration. To address this non-linearity, the data were fit with a log-linear regression of the form:  $C_{\text{tissue}} = \beta_0 + \beta_1 \ln(C_{\text{sed}} / f_i) + \beta_2 \ln(f_{\text{lipid}})$  where  $f_i$  is the fraction of organic carbon or fraction of iron in the sediments, for organics and metals, respectively. The  $\beta_1$  coefficients in the regression. The  $f_{\text{lipid}}$  term was excluded for metals. This formula reverts to the standard BSAF when the  $\beta_1$  equal 1. Individual tissue concentrations were matched to area-weighted average surface sediment concentrations based on animal home range. The regressions achieved statistically significant relationships for most species-contaminant pairs, often spanning orders of magnitude; maximum R<sup>2</sup> was 0.92 for 2,3,7,8-TCDD. Subsequent to the original work described in the 2014 proposed plan, an additional data set collected in 2012 above the head-of-tide on the Passaic was used as a validation data set for the original BSAF regression approach. In 6 of the 8 contaminant-species pairs reviewed, the new data validated the original regression analysis, and confirmed the extrapolation of the 2,3,7,8-TCDD regressions to sediment concentrations 10 times lower than those in the original analysis. This relatively simple but robust empirical approach was used to develop the site-specific sediment remedial goals for the ROD.

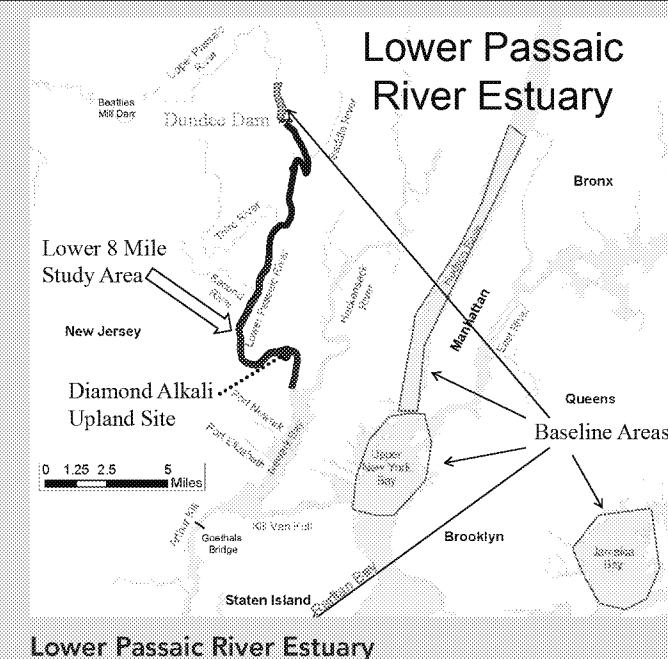
## Current Conditions

The Passaic River, located in the New York metropolitan area, was one of the major centers of the American industrial revolution starting two centuries ago. By the end of the 19th century, a multitude of industrial operations had located along the river's banks as the cities of Newark and Paterson grew. These industrial developments used the river for wastewater disposal. The Lower Passaic River was also used to convey municipal discharges. Together, these waste streams (industrial and municipal) have delivered a number of contaminants to the river, including, but not limited to polychlorinated dibenzodioxins and furans (PCDD/F), polychlorinated biphenyl (PCB) mixtures, polycyclic aromatic hydrocarbon (PAH) compounds, DDT and other pesticides, mercury, lead and other metals.

An important component of the development and urbanization of the Lower Passaic River was the channelization of the river, which permitted commercial vessels better access into the city of Newark from Newark Bay and the Kills. Maintenance dredging of the channel has largely ceased, resulting in the accumulation of a large volume of sediments. The coincidence of chemical disposal in the river along with the filling-in of the navigation channel, created an ideal situation for contaminated sediments to accumulate in the Lower Passaic River.

In addition to various other accidental and intentional releases to the Lower Passaic River, the river was significantly impacted by releases from the former manufacturing facility located at 80 Lister Avenue in Newark, New Jersey (located near RM3), which began producing DDT and other products in the 1940s. Between 1951 and 1969, the facility produced the defoliant chemical, known as "Agent Orange", among other products. A by-product of the manufacturing was 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), which was released into the river.

In 2016, the USEPA issued a record of decision requiring the remediation of the lower 8.3 miles of the Lower Passaic River estuary.



## Goal of the Analysis

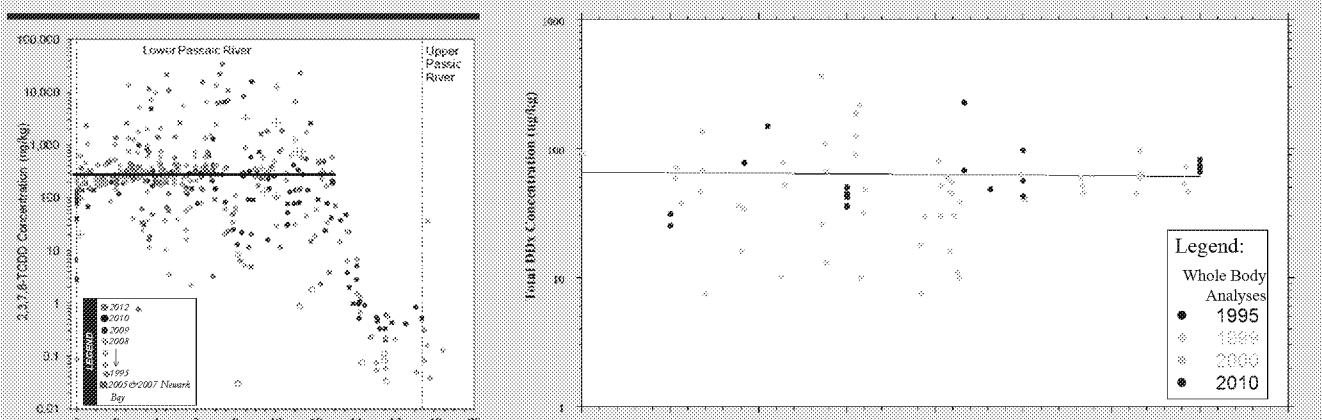
- Develop a basis to estimate sediment remedial action goals based on target fish levels.
- Develop quantifiable site-specific relationships between sediment and fish tissue concentrations for the major contaminants, including 2,3,7,8-TCDD, PCBs, DDT, dieldrin, PAHs, copper, lead and mercury.
- Fish included American eel, blue crab, mummichog and white perch.

## Background Data

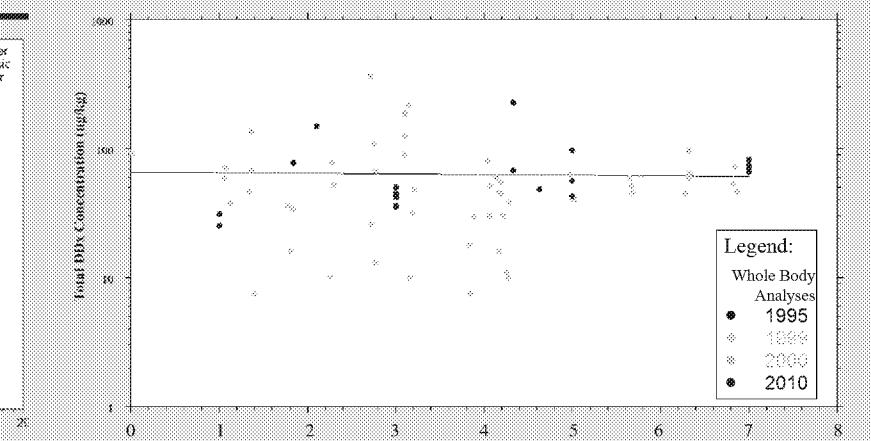
- NYC Harbor data obtained via multiple agencies provide the needed range in sediment exposure and fish tissue levels.
- Data from Upper Passaic River (above Dundee Dam) were reserved to validate model results.

## Site Data

### Contamination in LPR Sediments Shows Little Trend with River Mile Below RM 12

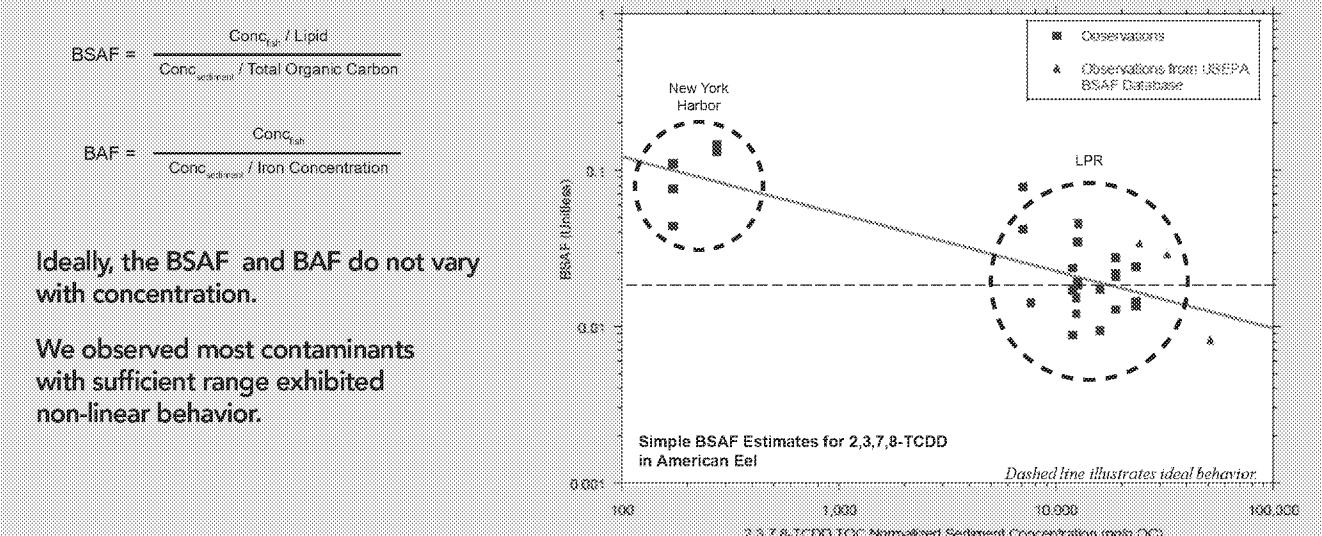


### Like Sediments, LPR Fish Tissue Shows Little Trend with River Mile



- Site data provide a narrow range of exposure and limited ability to estimate BSAF values at low concentrations.

## Simple (Linear) BSAF Results



## Non-Linear Regression Formulation

$$\ln(C_t) = \beta_0 + \beta_1 \ln(C_{\text{sed}}) + \beta_2 \ln(t_i) + \beta_3 \ln(f_{\text{lipid}}) + \epsilon$$

Where:

$C_t$  = Contaminant concentration in fish tissue

$C_{\text{sed}}$  = Contaminant concentration in the sediment

$t_i$  = Fraction lipid in fish

$f_{\text{lipid}}$  = Fraction organic carbon in sediment

$\epsilon$  = Normally distributed mean-zero random error

Exponentiating both sides results in the multiplicative model:

$$C_t = e^{\beta_0} \times C_{\text{sed}}^{\beta_1} \times t_i^{\beta_2} \times f_{\text{lipid}}^{\beta_3} \times e^{\epsilon}$$

Which can be solved for an estimate of a BSAF-like term:

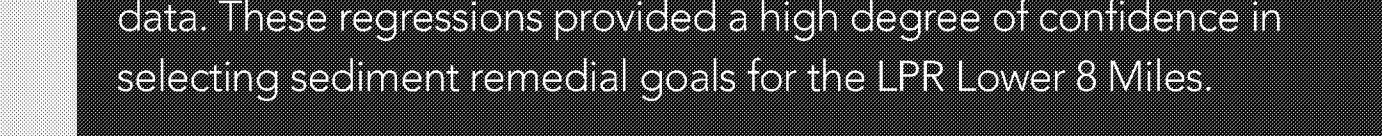
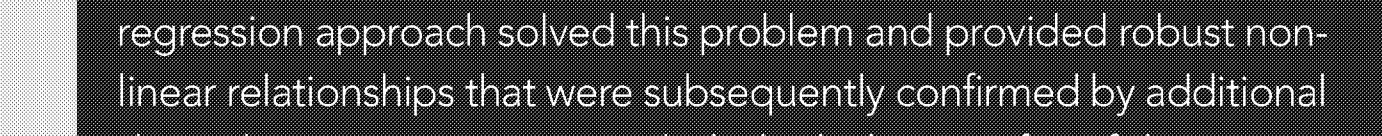
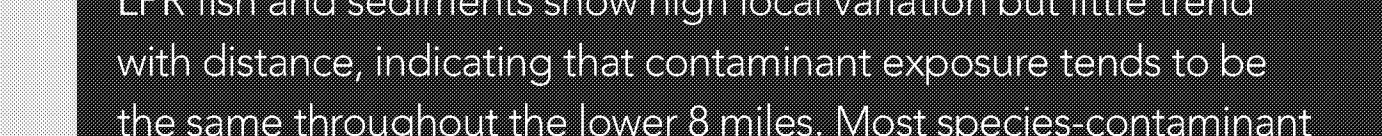
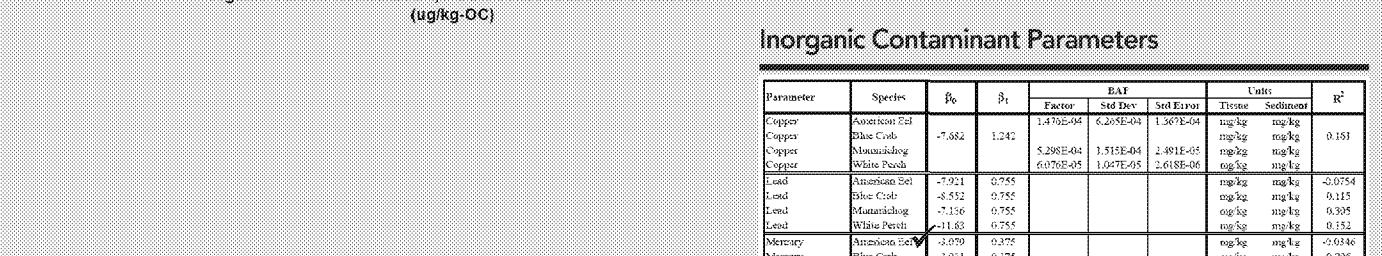
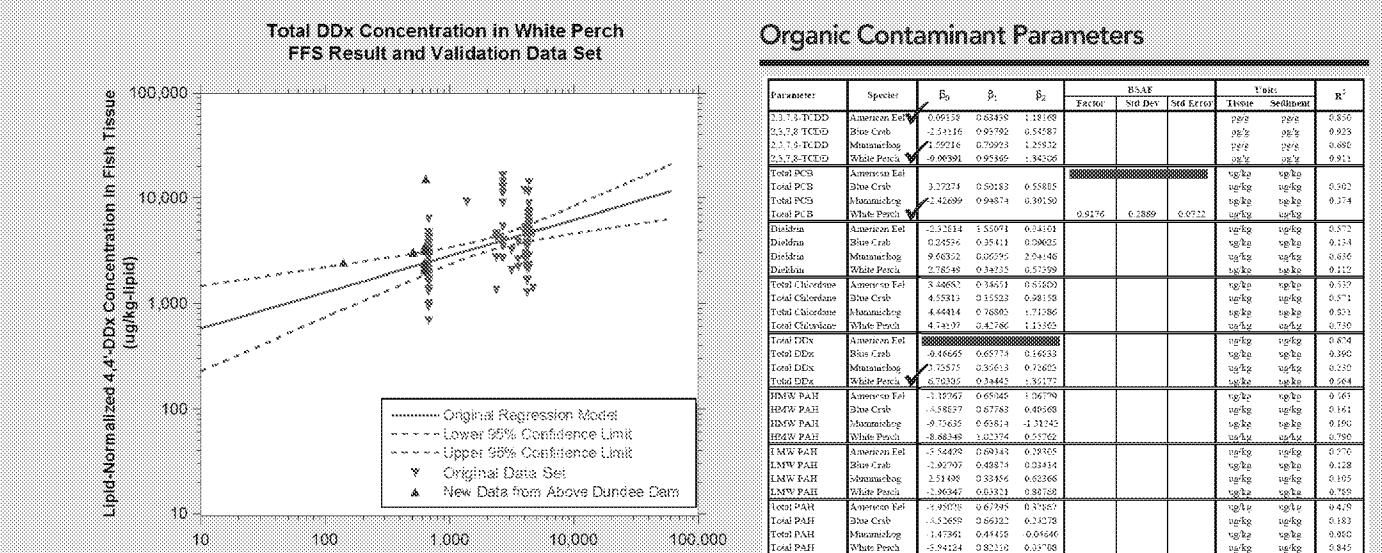
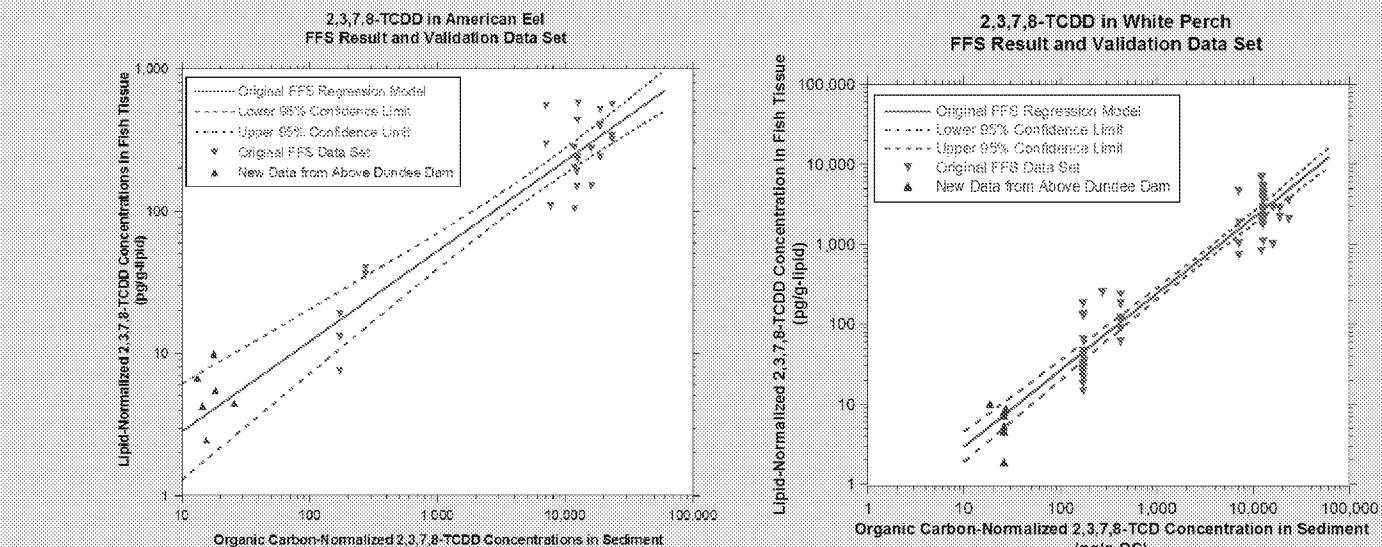
$$\frac{(C_t / t_i^{\beta_2})}{(C_{\text{sed}}^{\beta_1} \times f_{\text{lipid}}^{\beta_3})} = e^{\beta_0 + \beta_1 \ln(C_{\text{sed}}) + \beta_3 \ln(f_{\text{lipid}})} = e^{\beta_0} \times e^{\beta_1 \ln(C_{\text{sed}})} \times e^{\beta_3 \ln(f_{\text{lipid}})}$$

$\beta_0$  = Coefficients for species, species- $C_{\text{sed}}$ , and species- $f_{\text{lipid}}$  interactions

$\beta_1$  = Coefficient for inorganic regression analysis

## Results

- A model fit was developed for four species by 11 contaminants (44 pairs in all).
- Model achieved quantitative fit in most instances.
- Validation data set supported extrapolation of regression relationships to more than 1-fold lower concentrations for 2,3,7,8-TCDD.
- 6 of 8 models tested were validated by the additional data



✓ = Model parameters confirmed by data from above Dundee Dam.  
✗ = Model parameters not confirmed by data from above Dundee Dam.

## Conclusions

LPR fish and sediments show high local variation but little trend with distance, indicating that contaminant exposure tends to be the same throughout the lower 8 miles. Most species-contaminant pairs exhibited non-linear relationships with concentration when sediment concentrations varied by orders of magnitude. Our regression approach solved this problem and provided robust non-linear relationships that were subsequently confirmed by additional data. These regressions provided a high degree of confidence in selecting sediment remedial goals for the LPR Lower 8 Miles.